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INVESTIGATION ON WEAR RESISTANCE BEHAVIOR OF SIC FILLED HYBRID COMPOSITES

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ABSTRACT

Polymer composites and hybrid polymer composites are replacing many of the monolithic materials and alloys due to their higher strength to weight ratio, while apparently exhibiting excellent strength to corrosion and wear resistance. Investigation was carried out through experimental study on Silicon Carbide (SiC) filled, different combination of hybrid composites to determine the 'two body' abrasive wear behavior. Freshly fabricated Glass-Jute-Epoxy, Glass –Sisal-Epoxy and Glass-Rubber-Epoxy composites with different weight percentage of silicon carbide filler was subjected to two body abrasive wear test under normal room temperature in dry condition on pin-on-disc equipment using 300 grit SiC sand papers. Abrasive paper was stuck on to the rotating disc and test specimen was attached to the flat surface of the pin. The effect of filler content on the (0%,5%,10%) was studied for 20N load for different sliding distance (25m,50m,75m,100m). The results reveal that the material with increases in filler content is prone to higher wear resistance. The polymer composites with 10% SiC showed least wear loss in all the combination under consideration and lowest wear loss was achieved in glass rubber epoxy and10% SiC combination.

Key words: Polymer composites, hybrid composites, SiC, Fabrication

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1. INTRODUCTION

Generally the polymer composites are fabricated by various methods such as hand layup technique, vacuum molding, pressure molding and resin transfer mold techniques. The hand layup technique is comparatively suitable & popular method for laminated polymer composites due to easy accessibility of required facilities. In the present study also the composites are fabricated using hand layup technique. Polymer composites have been used for replacing many of metal matrix composites, they have been used for numerous mechanical and tribological applications such as bumpers, supporting stand, gears, bearings, brakes and clutches, cams, wheels [1]. They are potential elements for replacing conventional monolithic materials. Polymer composites are replacing materials at faster rate due to their ability to tailoring properties with use of filler materials like silicon carbide, coppersulphate,

graphite, tungsten carbide [2-4]. Out of two types of epoxy resins that is thermoplast and thermoset. Thermoset epoxy resin is extensively used as a matrix and studied for polymer composites structures as they exhibit higher mechanical properties, lower shrinkage, easily available, less moisture absorption, ease of manufacturing, excellent chemical and moisture resistance, good wet ability [5-7]. Wear is defined as the progressive loss of material due to relative motion between the surfaces in contact[8].The softer material will generally get worn out when comes in contact with harder material. Abrasive wear is caused when the harder material used, contain abrasive particle. These materials will contribute to the loss of material against moving surface [9-12]. There are two types of abrasive wear; they can be broadly classified as two body abrasive wear and three body abrasive wear. Two body abrasive wear is caused when the smoother material passes over the harder one and material loss occurs from the smoother surface. In three-body abrasive wear the harder material is made to move in-between two rotating smoother surface under consideration. The contact surrounding will determine whether wear is closed type or open type [13]. The study of two body abrasive wear is very important as it contribute to 40% of the overall material loss due to wear [14]. There is a significant difference between two-body and three-body abrasive wear. The two body abrasive wear produces 10 times more material loss than three body abrasive wear. That is, two body abrasive wear is undesirable due to high wear rates, activation of other wear mechanisms, and dramatic surface damage [15]. By using abrasive sand paper two body abrasive wear test can be conducted where abrasive surface is fixed and smother element is made to rotate. In reality many components for example shuttle tillage tools, wind blades and conveyor belts are also subjected to two body abrasive wear [16]. There were many types of low density polyethylene(LDPE) and other polymers which showed the lowest wear rate in abrasion against rough mild steel (comparatively smoother surface) and wear rate was increased and found to be highest against Silicon carbide abrasive paper with coarse grit size [17-19]. Many researchers have studied the abrasive wear behavior of polymer composites SiC and different filler material with use of the abrasive paper of 600 and 100 grit size [20-24]. Incorporation of fibers/filler into matrix show both positive and negative effect on mechanical and tribological properties [25-28]. Experimental study on three body wear behavior of SiC and Graphite powder fillers filled glass fabric vinyl ester composites proved that the SiC filled composites showed enhanced abrasion wear resistance in comparison to graphite filled composites [29]. Based on these referral works, we have tried different combination of composites filled with different percentage SiC as filler material to investigate further.

2. EXPERIMENTAL PROCEDURE

2.1. Material and Specimen Details

The raw material used in fabrication of composites by hand layup technique are; Glass Fabric, Jute Fabric, Rubber Particles, Sisal Fiber and Epoxy Resin. Glass-Jute fabric with epoxy resin in 60:40 ratio was used for unfilled composites and for others percentage of resin was varied according to the quantity of filler content used (35%E,5%SiC & 30%E,10%SiC). Other different material combinations used in this study are Glass fabric -sisal with epoxy resin in 60:40 ratio and Glass fabric- rubber particles with epoxy resin in 60:40 ratio was used. The resin content was varied based on the filler content quantity used in it. All the polymer composites are fabricated by hand layup technique are pre cured at normal room temperature; the pre cured material is subjected to the pressure of 14Mpa at $100^{o}C$. The specimens used for wear test are in dimensions of 10mm×10mm×3mm. Two body abrasive wear test was conducted on a pin-on-disc apparatus at normal room temperature.

2.2. Fabrication of Composite Specimens

Fabrication process is done in three stages (i) preparation of resin by adding filler material to it and mixing it uniformly by using mechanical stirrer. (ii) Removing the moisture content in the fabric by exposing it hot sun (iii) Mixing of hardener to the resin. To start with, 5 % SiC filler of total weight of the composites is mixed with resin by using mechanical stirrer. In second stage the moisture content in

the fabric is removed for proper bonding between the matrix and the fiber. In third stage the hardener is added to the epoxy in the ratio 100:38 on weight basis and the hardener mixed resin is applied on the glass fabric. Using roller, the excessive resin and entrapped hole or air bubble is removed from the adjacent layers. The laminate is built up till the thickness of 3mm and tabs are used for maintaining uniform thickens throughout the laminate. The laminates are cured at room temperature and pressure of 14bar is applied for duration of 24-48 hours.

The fiber to matrix ratio is 60:40 for unfilled composites and 60:35:5 and 60:30:10 for 5% & 10% SiC filled composites. The laminates are fabricated to the dimension of 300mm×300mm×3mm and specimens are cut to require dimensions using wire saw machine.

3. TRIBOLOGICAL CHARACTERISTICS TEST

As the name indicates it deals with study of wear behavior and parameters affecting it like friction and wear. The composites materials which are fabricated by land layup technique are subjected to different kinds of tribological test. To analyses the wear properties of the component two body abrasive wear test was conducting using the pin on disc. Wear test is conducted according to standard dimension G99 it doesn't have any fixed constraint. In the present study the dimension the components used for wear test are 10mmX10mmX3mm. Two body abrasive wear test is conducting for 20N load and for different abrading distance of 25m, 50m, 75m and 100m. The specimen is attached to the flat surface of the pin and 300 grit size SiC sand paper is stick to the surface of the disc. For each trail the fresh sand paper is used. The different test parameters used in two body abrasive wear test are material combination, sliding distance, speed of rotation of disc, and loading condition.

3.1. Experimental Calculations

1. Velocity (v) is calculated by using following formula

$$v = \frac{\pi DN}{60000} \quad \text{m/sec} \qquad (3.1)$$

Where D=diameter of wheel in mm.

N= speed of wheel in rpm

2 Time (t) is calculated by using following formula

$$t = \frac{s}{v} \quad \text{sec} \qquad (3.2)$$

Where s = Abrading distance in meters

v = velocity of wheel in m/s

3 Wear Volume (V) is calculated by using following formula

$$V = \frac{m}{\rho} \quad \text{mm}^3 \qquad (3.3)$$

Where m= mass loss in gm

ρ = density in g/mm^3

4 Specific Wear Rate (K_s) is calculated by using following formula

$$K_s = \frac{V}{LD} \quad \text{m}^3\text{/N-m} \qquad (3.4)$$

Where V = wear Volume in m^3

L = Load in N

D = Abrading distance in m

Table 3.1 Two-body abrasive wear tests for 20N load for different material combination with SiC as filler

Wear Loss in (gm)				
Material Combination	**ABRADING DISTANCE (M)**			
	25	**50**	**75**	**100**
G-J-E	0.0526	0.0601	0.0694	0.0761
G-S-E	0.0465	0.0638	0.0761	0.0869
G-R-E	0.0531	0.0630	0.0724	0.0765
5%SiCG-J-E	0.0471	0.0531	0.0612	0.0698
5%SiCG-S-E	0.0418	0.0598	0.0703	0.0834
5%SiCG-R-E	0.0420	0.0523	0.0636	0.0700
10%SiCG-J-E	0.0419	0.0471	0.0551	0.0632
10%SiCG-S-E	0.0394	0.0544	0.0647	0.0760
10%SiCG-R-E	0.0333	0.0428	0.0560	0.0604

3.2. Wear Loss

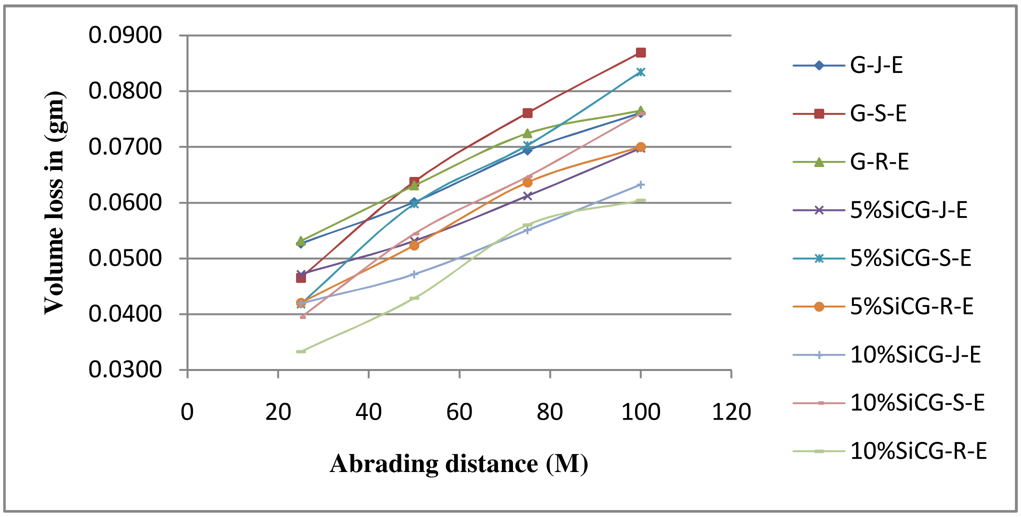

Figure 3.1 Wear loss in volume against abrading distance for 20N load

3.3. Specific Wear Rate

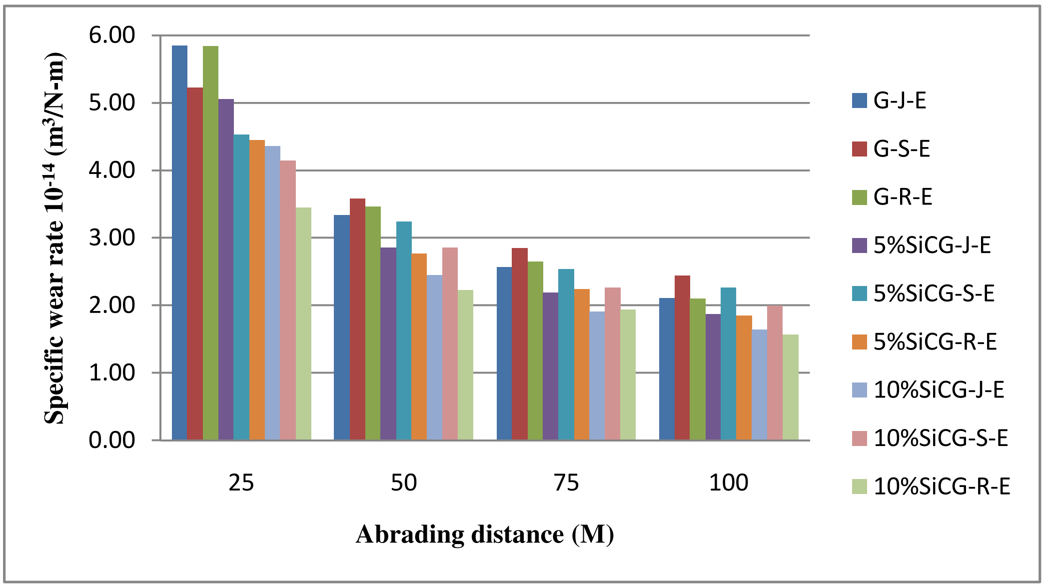

Figure 3.2 Specific wear rate against abrading distance for 20N load

4. RESULTS & DISCUSSION

4.1. Wear Loss

The graphical representation of wear volume loss against the abrading distance of unfilled and SiC filled composites at 20N load against 300 grit SiC is shown in Figure 3.1 It is evident from the wear test that the volume loss of the material increases with increase in the abrading distance. During the test, the worn out layer of glass fibre, epoxy material and the broken SiC particles gets deposited on the surface of the sand paper. The particles may remain on the contact surface of the sand paper and specimen under test. The wear resistance of the material increases with increase in the filler content as SiC is ceramic material which resists wear. The wear loss of 10% SiC filled composites was less when compared to all other combination. The lowest wear loss was observed in 10%SiC-G-R-E for 25m abrading distance while loss amounting to 0.0326gm at 500rpm and 20N load. This shows that this combination of material is harder than any other combination under consideration. The maximum wear loss was observed for G-S-E combination and hence it can be considered as the smoother material among the combination subjected to this test.

4.2. Specific Wear Rate

The graphical plots of specific wear rate versus abrading distance of SiC filled and unfilled composites at 20N load against 300 grit size SiC sand paper is shown in figure 3.2. Other than the cumulative wear loss, the specific wear rate reduces significantly with increase in abrading distance from 25m to 50m in exponential order. For further increase in the abrading distance, decrease in specific wear rate was considerably slower and the decrease in wear rate from 50m to 100m was almost linear. The reason may be; at the initial stage the specimen is in direct contact with the SiC abrasive paper the smoother epoxy resin part gets exposed to sand paper directly and thus wear rate is very high. As the abrading distance increases, the worn out layer of glass fibre, epoxy material and the broken SiC particles gets deposited on the surface of the sand paper and makes it smoother. The epoxy layer in the specimen which is smoother compared to fiber erodes fast and gets deposited on the surface of the sand paper first, following which the stronger fibers comes in contact with abrasive layer. Resistance offered to the wear by the fibers is comparatively more than the epoxy resin. Hence the wear rate decreases. This is because much higher amount of energy is required to break down the fibers leading to slower material removal rate and thus specific wear rate is reduced. The obtained specific wear rates are in agreement with the findings reported in the literature [30-31]. The result clearly indicates that the specific wear rate depends on material combination, abrading distance and grit size of abrasive papers used. The matrix used in this work is thermoset and the reduction in specific wear rate is after incorporation of SiC as filler in to the considered combination of composites.

4.3. SEM Analysis

SEM analysis was carried to investigate the reason for variation in the wear loss and wear resistance of different material combination. Polymer composites are non-conductive and hence cannot be used for performing SEM analysis directly. To make these materials conductive coating is done on the samples by the process called sputtering. To perform SEM analysis sputtering was done using 'Quarum Sputtering Machine' of model reference 'Q150TES' was used. The material used for sputtering was gold and palladium (Au-Pd). Mixture was coated on the surface of the material to be tested. This process of sputtering was carried out in a closed chamber for duration of 60 minutes.

Figure 3.3 Q150T ES (Quarum) Sputtering machine

Once sputtering is done on the material surface they become conductive and these materials can be used for conducting SEM test. SEM test was conducted at authorised and authenticated test centre.

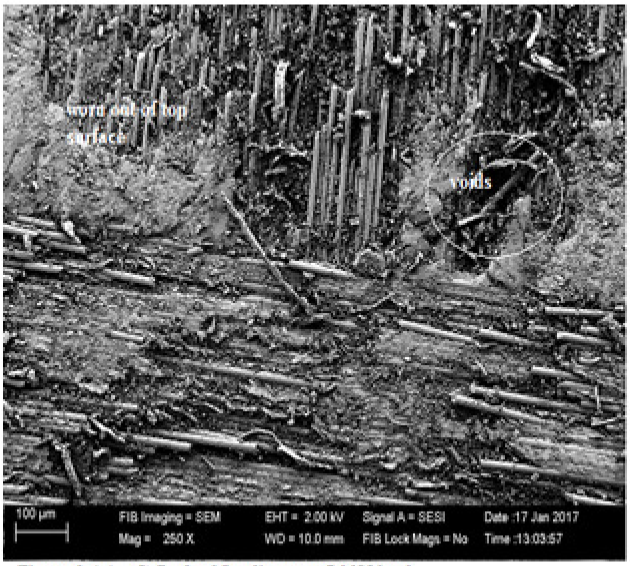

Figure 3.4 A G-J for 25m distance @20N load

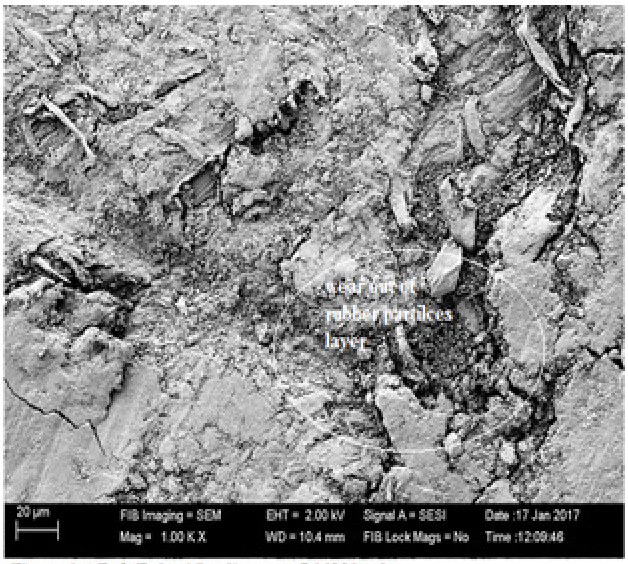

Figure 3.4 B G-R for 25m distance @20N load

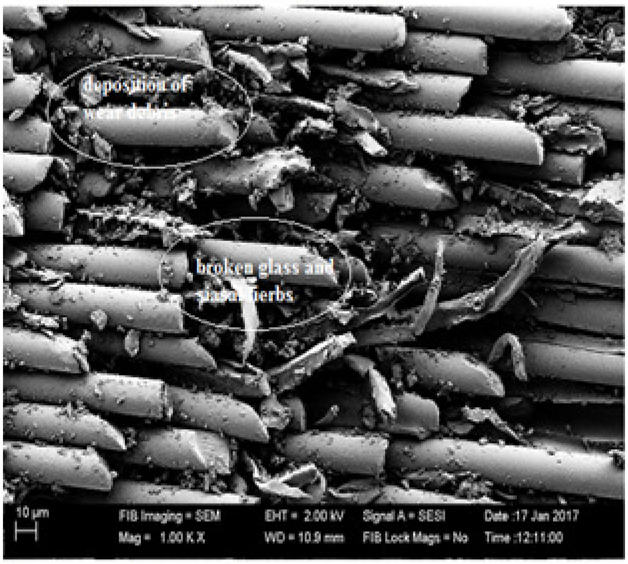

Figure 3.4 C G-S for 25m distance @20N load

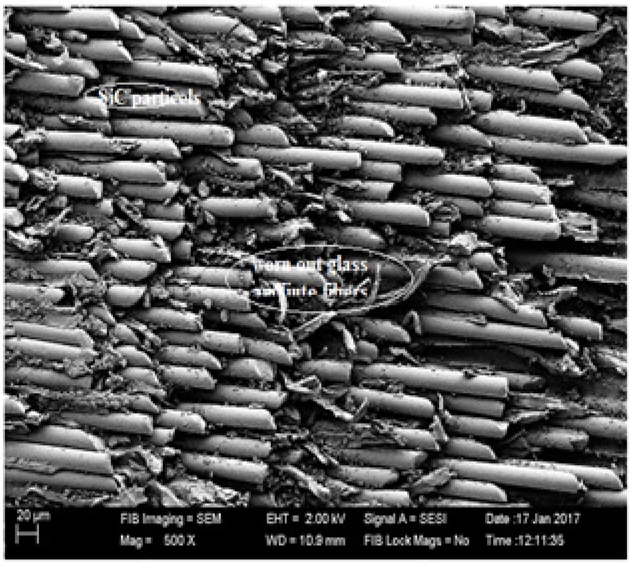

Figure 3.4 D G-J-5%SiC for 25m distance @20N load

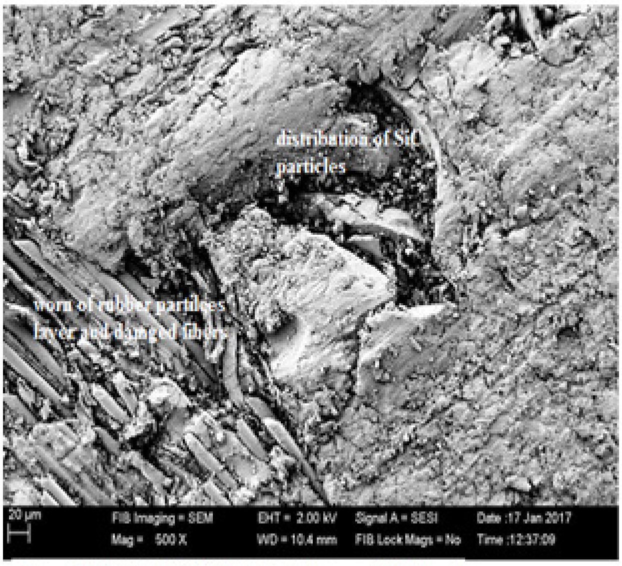

Figure 3.4 E G-R-5%SiC for 25m distance @20N load

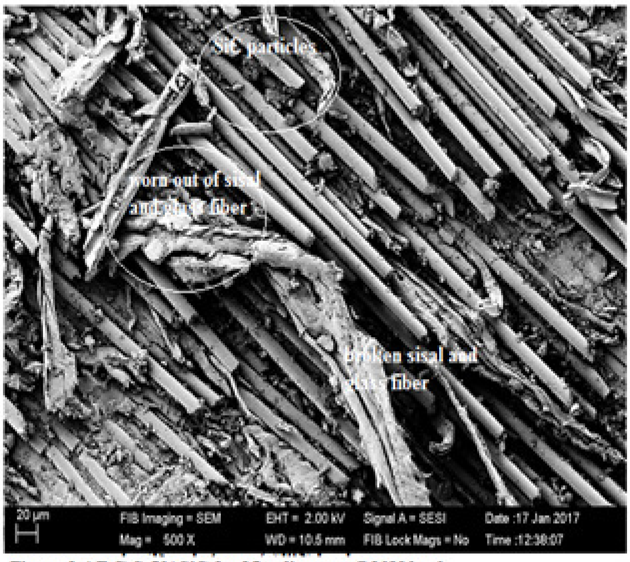

Figure 3.4 F G-S-5%SiC for 25m distance @20N load

Figure 3.4 SEM Images of wear test samples for 20N speed at 500Rpm

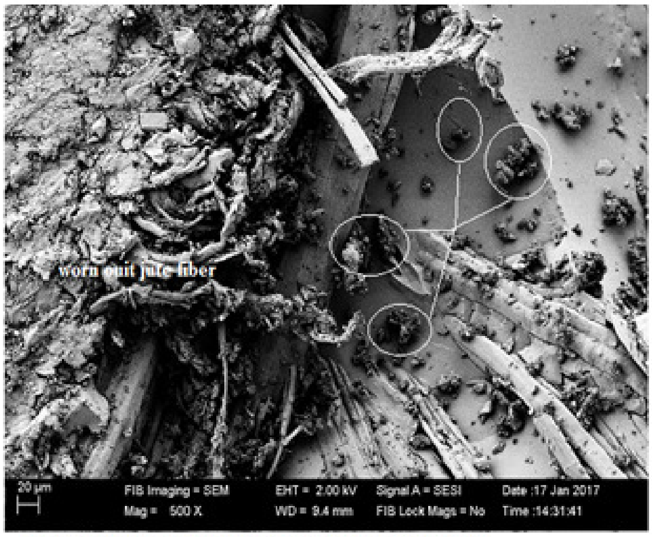

Figure 3.4 G G-J-10%SiC for 25m distance @20N load

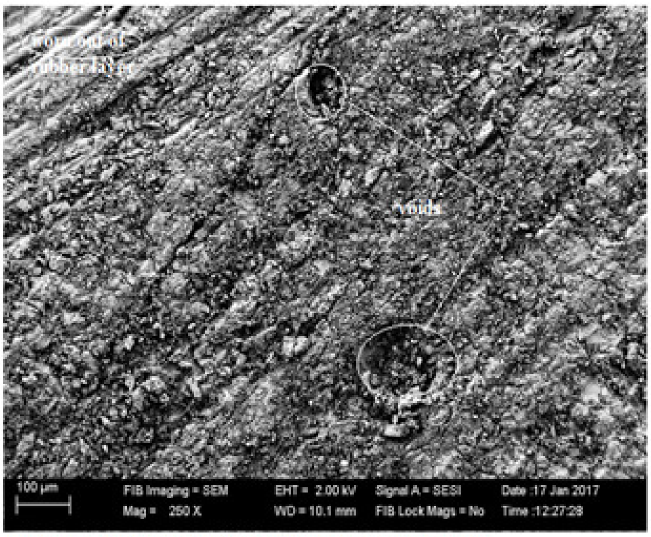

Figure 3.4 H G-R-10%SiC for 25m distance @20N load

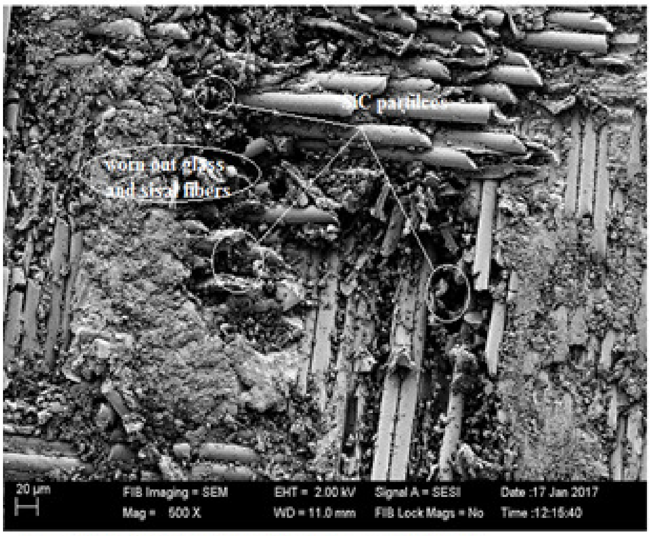

Figure 3.4 I G-S-10%SiC for 25m distance @20N load

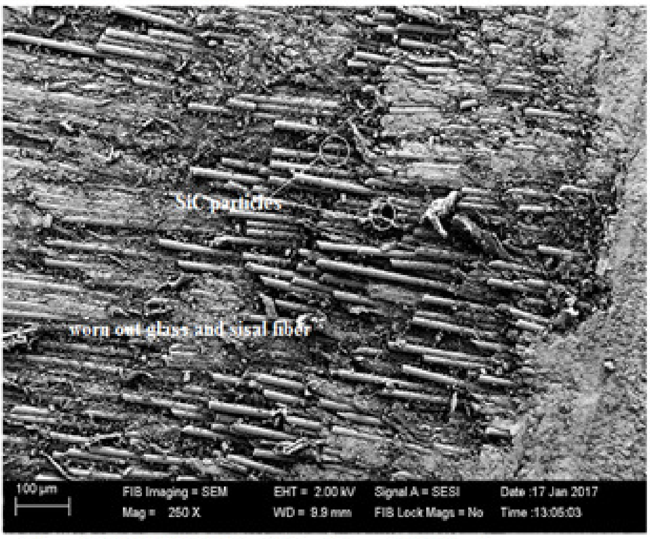

Figure 3.4 J G-S-5%SiC for 100m distance @20N load

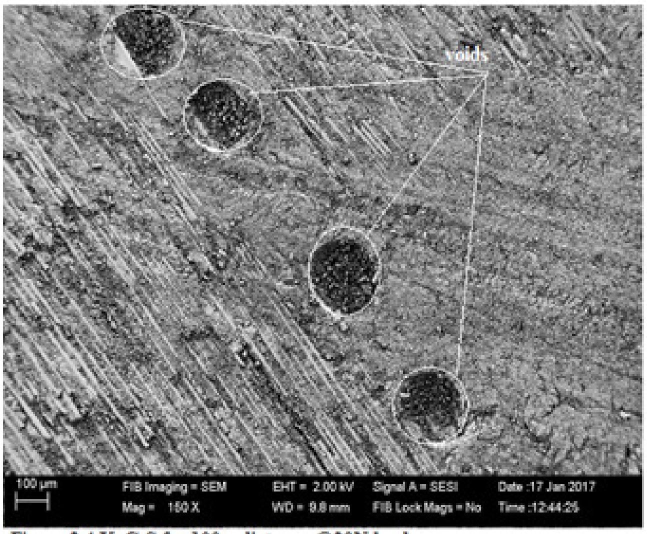

Figure 3.4 K G-S for 100m distance @20N load

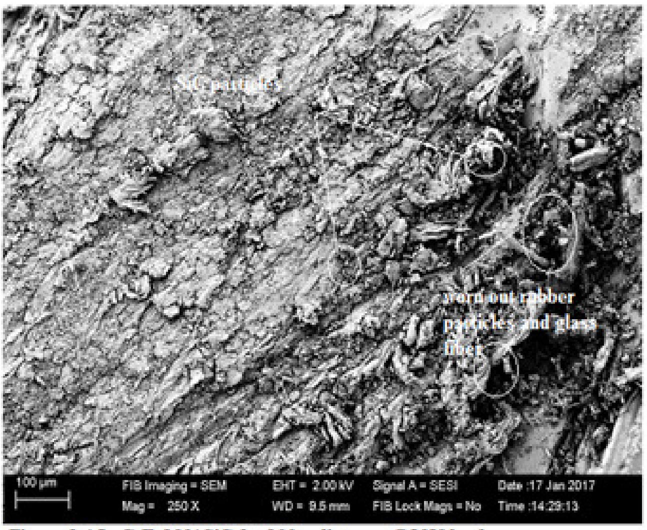

Figure 3.4 L G-R-10%SiC for 100m distance @20N load

Figure 3.4 SEM Images of wear test samples for 20N speed at 500Rpm

From the SEM images of different sample following conclusions can be drawn

The SEM images exhibit the wear of glass/jute fibre composites along the direction of rotation of specimen. Figure 3.4 A, shows micro-pitting are present on the worn surface due to adhesion between specimen and the counter face. Higher wear rate is observed at initial stage since the lower strength epoxy resin material is exposed to the hard sand paper. In some of the regions epoxy resin has been detached due to the plastic deformation and debris is created on the surface of the composites. Figure 3.4 B shows the worn out of glass fibre and rubber particles due to high pressure contact between specimen and the abrasive. Rubber particles are detached from the surfaces in many regions exposing the glass fibres to the abrasive paper. Wear loss in this particular combination is less due to the sticking of the rubber particles on the surface of the sand paper and making it smooth and preventing higher wear loss. Figure 3.4 C, shows the wear structure of the surface due to movement of the specimen over the abrasive under load. Since both the fibres offer resistance to the wear, the wear loss is less compared to other combinations. At initial stage, epoxy is worn out exposing the fibre material. Figure 3.4 D shows the distribution of SiC particles on the worn surface. Only top layer of the epoxy resin gets eroded as the filler material offers more resistance than unfilled epoxy resin exposing glass and jute fibre partially to the abrasive surface. Figure 3.4 E, shows the worn out surface of 5% SiC filled glass-rubber and epoxy composites. The wear rate of epoxy is reduced comparatively to unfilled composites and shows improved resistance. Rubber particles are detached at certain region and expose the fibres SiC particles and debris are deposited at the worn out surfaces. Figure 3.4 F, shows the worn surface of 5% SiC filled glass-sisal and epoxy resin. At regions between the fibres shows the partial distribution of SiC particles. Once the epoxy layer gets worn out sisal and glass fibres are exposed to abrasive particles and the SEM images shown broken out glass and sisal fibres. Figure 3.4 G, show the distribution of SiC particles at few regions and rubber particles is peeled out from the surface and broken jute fibres are visible. This makes the surface more prone to wear and reduces the wear resistance capacity. Figure 3.4 H, shows the images of 10%SiC filled glass and rubber particles. As the SiC mixes with epoxy resin & rubber particles, makes the rubber particles brittle and causes micro cracks on the surface. As the surface become harder, the wear resistance increases and causes less material removal from the surface and SEM images shows distribution SiC particles on the surface of the polymer composites. Figure 3.4 I, shows the 10%SiC filled glass and sisal composites. It shows the clogging of material at certain region and epoxy material removal from the surface in which SiC particles are clearly visible along with debris and broken particles of fibres in it. Figure 3.4 J, shows the worn out of glass-sisal fibre with 5% SiC filled composites under sliding distance of 100m with

load of 20N. Figure 3.4 K, shows the worn out layer of polymer composites with glass and sisal fibres. Higher wear rate can be observed in this material as there were many voids present in the image. Additionally this reflects that, during the wear test due to increase friction between the specimen and abrasive, the heat generated in the contact surface increases and makes the material soft causing voids and micro cracks in the material surface. There may be also chance of secondary wear due debris get placed between specimen and abrasive which increases the wear loss. Figure 3.4 L, shows the worn out surface of 10% SiC filled glass rubber particles with 100m sliding distance for a load of 20N. As the sliding distance increases heat generated at the contact surface makes the material soft. As the rubber becomes soft it gets stuck to the surface of abrasive disc and makes it smooth. Hence the wear rate of the material decreases causing clogging of rubber particles on the surface of the abrasive. SEM images reveal presence of some SiC particles on the surface and some debris have filled the pits.

The results from SEM images reveal the composites with rubber and glass fibres shows higher resistance by making the abrasive particles smoother by deposition of rubber particles on the surface of abrasive. By using the SiC filler material the surface of the material becomes hard. As SiC particles is a abrasive particle, pulling out or detachment of fibres from the matrix is difficult to reduce wear rate. The reason behind reduced wear resistance in the glass and sisal combination is uni-directional orientation of sisal fibre in the combination as bi-directional woven fabric material offers higher resistance compared to uni-directional fibres. This is observed from the SEM images.

5. CONCLUSIONS

In present study wear test was conducted on polymer matrix composites with ceramic filler with a view of investigating variation of the wear resistance. However some results shows positive effects and some results show negative effects. From the experimental investigation of SiC hybrid composites on wear test and SEM images, the following conclusions can be drawn;

- Unfilled polymer composites shows higher wear loss when compared to composites filled with SiC filler.
- The wear resistance of the material increases with increase in the filler content of SiC in all the material combination subjected to test.
- Wear loss of the material increases with increase in the abrading distance irrespective of the combination used.
- The material combination with Sisal and Glass fibre shows maximum wear loss when compared all other combination for same testing condition.
- In each combination, 10% SiC filled polymer composites shows least wear loss than 5%SiC filled and unfilled composites.
- Rubber and glass epoxy composites filled with 10%SiC shows least wear loss of all the combination for 25m distance.
- The SEM micrograph images at certain combination shows that there may be also chances of secondary wear due to debris getting placed between specimen and abrasive and also show some voids. This may be the reason behind the higher wear loss for glass and sisal combination.
- The SEM micrograph shows formation of line on the surface which confirms the wornout of SiC particles when it travels over the surface.
- When specimen travels over the surface of disc with abrasive paper, heat gets generated at the sliding surface resulting in agglomeration which is observed in rubber and glass polymer composites.

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